ALGAL EPIPHYTES OF SUBTIDAL *ZOSTERA MARINA* L. ON THE SOUTH COAST OF IRELAND

John CULLINANE*, Jacqueline O MAHONY* and Padraig WHELAN*

ABSTRACT. – The algal epiphytes of *Zostera marina* were studied at six sites along the south coast of Ireland. The species were recorded and their location on the different parts of the host were noted. Sixteen diatoms and twenty-five macroalgae were found. Epiphytes were most abundant on the outermost leaf and least abundant on the fourth outermost leaf. In contrast to previous reports rhizomes were found to be an important site for algal epiphytes as were the dead leaf sheaths. Whereas previous studies at Roscoff found no difference in the epiphytes on either side of the leaf, the genus *Fosliella* was shown in the present study to favour the adaxial side. Comparison with other surveys are limited since there are no reports available on algal epiphytes from subtidal *Zostera* in western Europe.

KEYWORDS : *Zostera marina*, *Fosliella*, epiphytes, subtidal, algae, Ireland.

Zostera marina L. a flowering plant of the family Potamogetonaceae grows abundantly along the coast of Ireland from the intertidal to depths of 10 m below Chart Datum (C. D.). The plant grows by a branched underground horizontal rhizome which lies buried in the mud, sand or shingle, anchored by roots which occur on the lower side. The leaves are produced from a meristem at the apices of the rhizomes and grow as upright groups of 6 to 8 leaves. New leaves are produced at the rate of one every 14 days approximately with the old leaves being cast off at approximately the same rate. Subtidal *Zostera* plants usually have six to eight leaves present at a time with the oldest (but not necessarily the longest) leaf, (leaf 1), on the outside and the progressively younger leaves (leaves 2, 3, 4, 5, 6, etc.) arranged alternately inside of this. Each leaf has a basal leaf sheath closely applied to the leaf but the dead leaf sheaths of former leaves usually persist entangled with the rhizomes and roots (rhizomatic parts).

An examination of the literature shows that *Zostera marina* in various parts of the world supports a host of algal and invertebrate epiphytes. However, very

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few reports exist of the distribution of the epiphytes on the different parts (roots, rhizomes, leaf sheaths and different aged leaves) of the *Zostera*. In Ireland no such report exists for either the intertidal or subtidal *Zostera*.

OSTENFELD (1908) found that diatoms, *Ceramium* Roth and *Ectocarpus* Lyngbye were very abundant on eelgrass (*Zostera*) leaves in Danish waters. VAN DEN ENDE & HAAG (1963) reported some 12 species of blue green, green and red algal epiphytes of *Zostera* from Roscoff (France) and were the first to report on the distribution and the position of the epiphytes on the eelgrass shoots in relation to the age of the leaves. DEN HARTOG (1970) listed more than 100 species of algae epiphytic on eelgrass. HARLIN (1980) in a literature review listed 91 microalgae, 121 macroalgae and 129 invertebrate species as epiphytes of *Zostera marina*. JACOBS & NOTEN (1980) recorded 199 diatom taxa as epiphytes of *Zostera*. JACOBS, HERMELINK & VAN GEEL (1983) reported the occurrence of *Zostera marina* epiphytes from fourteen intertidal stations at Roscoff. Some authors (FELDMANN, 1954, and DEN HARTOG, 1976) noted the restriction of specific epiphytes to *Zostera marina* including *Fosliella lejolisii* (Rosan.) Howe, (SUNESON, 1943; DAWSON, 1960) but this species has since been found on algae (CHAMBERLAIN, 1977; COPPEJANS, 1980).

Apart from the studies at Roscoff (France) by VAN DEN ENDE & HAAGE (loc. cit.) and JACOBS et al. (loc. cit.) there appears to be no other data on the seasonality and distribution of algal epiphytes of *Zostera* from western Europe and the data from those two studies are somewhat contradictory.

DESCRIPTION AND METHODOLOGY

A study was carried out of the algal epiphytes of *Zostera* at six subtidal sites along the south coast of Ireland (fig. 1) to determine the epiphytes present and their preferences if any for the different parts of the host plant. Table 1 gives a brief description of the six study sites including depths (in meters relative to C.D.). The salinity at all sites was approximately 32 ‰. As can be seen from Table 1, the substrate varied considerably between the sites. Likewise the extent and depth distribution varied between sites e. g. in Ventry Bay *Zostera* is extremely abundant and widespread (WHELAN & CULLINANE, 1983) growing from near C.D. to approximately 11 m below C.D. (making it the deepest growing *Zostera* bed in western Europe). At most other sites *Zostera* was less abundant and confined more to shallow water of not more than 3 m below C.D. At the greater depths in Ventry Bay the *Zostera* plants were reduced in size and density and algal epiphytes were almost completely absent. To eliminate the variation in the epiphyte flora with depth all sampling was carried out between C.D. and 2 m below C.D.

Sampling consisted of collecting 15 vegetative *Zostera* plants by SCUBA. This was shown to be the minimum number of plants necessary to obtain a representative sample of the epiphytes present at each site. A total of 265 *Zostera* plants were collected and examined. In the laboratory each plant was studied and the

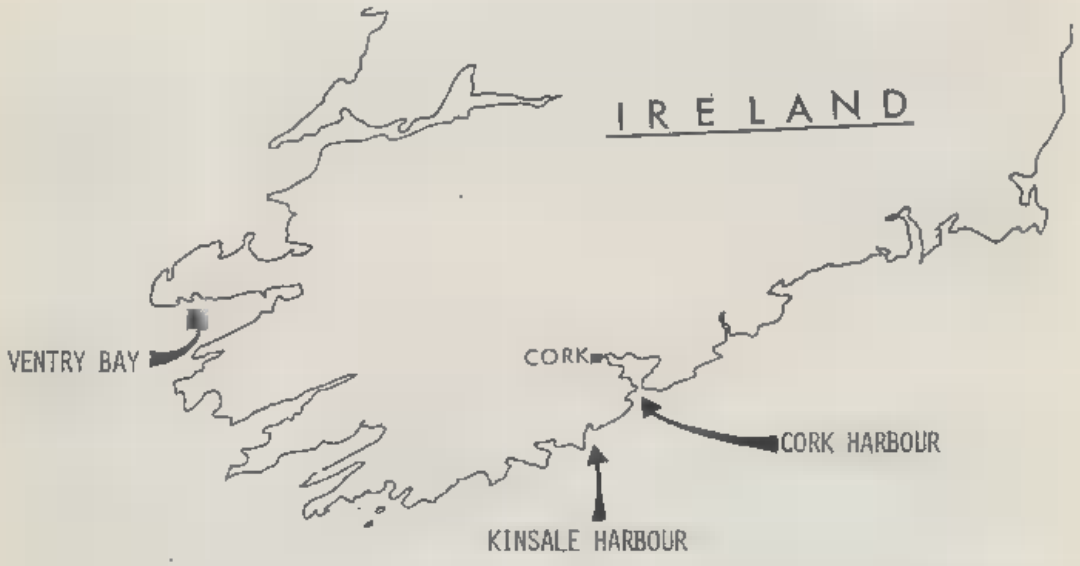

Fig. 1. — Map South coast of Ireland showing location of Ventry Bay County Kerry, Kinsale Harbour County Cork and Cork Harbour.

Site	Coordinates	Depths	Sampling Dates	Substrate and General Conditions
Cork Harbour				
Currabinny (1)	W800625	C.D. level	16.01.1982 23.02.1982	Sand over anoxic mud, turbid, Zostera meadow.
Spike Isl. (2)	W805640	1m.	16.01.1982 23.02.1982	Mixture of shells, mud and sand, turbid and silty with scattered Zostera.
Whitebay (3)	W825605	2m.	12.10.1981 16.01.1982 13.02.1982	Coarse sand, semi-exposed, dense clumps of Zostera.
Kinsale Harbour				
Money Point (4)	W660490	C.D. level	06.08.1981 27.01.1982 04.03.1982	Sand over anoxic hard mud. Calm and clear with a thin covering of widely separated Zostera.
Charles Fort (5)	W650480	2m.	06.08.1981 04.01.1982 06.03.1982	Pebbles, stones and sand, calm and clear with Zostera in small clumps.
Ventry Bay				
Cuan Pier (6)	V385980	1m.	04.09.1981 10.12.1981 12.12.1981 27.02.1982	Pure fine sand, clear and calm with a continuous meadow of Zostera.

Table 1. — Location and brief description of the six study sites along with the depths and dates of sampling.

presence of the various epiphytes present on the different plant parts were tabulated for each sampling at each site. The percentage of leaves 1 to 4 which had macroalgal epiphytes was determined so as to study the preference of the algal epiphytes for the different aged leaves. In the plants collected in Ventry a study

was made of the percentage cover of the crustose red algal genus, *Fosliella* Howe, to determine its seasonality, its distribution along the leaf from base to tip and its distribution on either side of the leaf. The outermost leaves from the Ventry plants were divided according to their lengths into six size classes and the mean percentage cover of *Fosliella* was determined for each of these size classes to examine the relationship between the colonization by *Fosliella* and the length of those leaves.

The nomenclature and authorities for the algae are according to PARKE & DIXON (1976).

RESULTS

Sixteen diatoms were recorded during the study (Tab. 2). Fourteen of the diatoms were found at Money Point and 6 of these were not found at any other site. Twenty-five epiphytic macroalgae and one blue green alga were recorded at

	Ventry				Money Point			Currabinny		Charles Fort			Spike Isl.		Whitebay		
Diatoms (16)	Sept.	Oct.	Dec.	Feb.	Aug.	Jan.	Mar.	Jan.	Feb.	Aug.	Jan.	Mar.	Jan.	Feb.	Oct.	Jan.	Feb.
(Bacillariophyceae)																	
Biddulphia aurita	+					+	+		+			+	+				+
Biddulphia sp.	+					+	+		+				+				+
Chaetoceros sp.						+											
Cocconeis sp.				+		+											
Coscinodiscus sp.	+	+		+		+	+		+								
Grammatophora sp.						+	+					+		+			
Licmophora sp.						+											
Navicula spp.		+				+	+		+			+				+	
Nitzschia closterium						+	+					+					
Pinnularia sp.						+											
Pleurosigma angulata		+					+										
Schizonema sp.																	
Stauroneis sp.						+											
Striatella unipunctata		+	+														
Surirella sp.						+											
Synedra sp.		+				+	+	+						+			

Table 2. — List of the diatoms recorded at the different sites and the dates of recording.

the different sites (Table 3), with an overall ratio of 16 Rhodophyta to 5 Phaeophyta. In the case of all samplings the Rhodophyta species were more numerous than the Phaeophyta as is shown in Table 3. *Cladophora* Kützing was the only genus found at all six sites. *Ceramium rubrum* (Huds.) C. Ag. and *Plocamium cartilagineum* (L.) Dixon were found at five sites. *Pilayella littoralis* (L.) Kjellm. was recorded only at Ventry during September and October but this epiphyte is known to the authors to be extremely widespread and abundant during

Macroalgae (25)	Ventry				Money Point			Currabiany		Charles Fort			Spike Isl.		Whitebay		
	Sept.	Oct.	Dec.	Feb.	Aug.	Jan.	Mar.	Jan.	Feb.	Aug.	Jan.	Mar.	Jan.	Feb.	Oct.	Jan.	Feb.
(Cyanophyceae)																	
Oscillatoria sp.											+						
(Chlorophyceae)																	
Cladophora sp.	+	+	+	+	+	+	+	+	+	+	+	+	+		+		+
Enteromorpha sp.	+				+			+		+							
Ulva lactuca		+						+		+		+					
(Phaeophyceae)																	
Dictyota dichotoma				+													
Ectocarpus sp.										+							
Halopteris filicina		+															
Pilayella littoralis	+	+															
Punctaria sp.	+																
(Rhodophyceae)																	
Antithamnion spirographidis						+	+								+		
Antithamnion sp.						+	+										+
Audouinella floridula	+																
Audouinella sp.	+	+				+											
Bonnemaisonia asparagoides																	
Ceramium rubrum		+	+					+	+	+	+	+	+		+		
Fosliella lejolisii		+															
Fosliella limitata		+															
Fosliella zinutula				+													
Fosliella sp.	+		+							+					+		
Gelidium sp.								+			+	+					
Plocamium cartilagineum			+			+							+		+		
P. cart. var uncinatum	+	+	+	+		+		+	+				+	+	+		
Polysiphonia nigrescens						+											
Polysiphonia sp.					+	+	+	+		+	+	+	+				
Rhodophyllis divaricata													+				
Ratio Rhodophyta to Phaeophyta	4:2	5:2	4:0	2:1	1:0	7:0	3:0	5:0	4:0	3:1	3:0	3:0	6:0	1:0	5:0	∞	1:0

Table 3. — List of the macroalgae recorded at the different sites and the dates of recording.

early summer. JACOBS et al. (1983) likewise noted luxurious growths of Ectocarpaceae covering the shoots in Spring. Ventry site had the greatest diversity of macroalgae (16 species with a ratio of 9 Rhodophyta; 3 Phaeophyta; 3 Chlorophyta). Money Point, however had a greater diversity of diatoms. Whitebay had the lowest diversity of algae (7 species), probably due to the effects of exposure and current (VAN DEN ENDE & HAAGE loc. cit.).

JACOBS et al. (loc. cit.) noted the «remarkable phenomenon of no algae on leaf sheaths» whereas it was found in the present study that nearly all diatoms were found on the rhizomes and/or dead leaf sheaths, with only two genera, *Coscinodiscus* and *Cocconeis* found on the leaves. The latter forms a crust and can be regarded as pioneer vegetation (SIEBURTH & THOMAS, 1973).

Of the macroalgae, *Fosliella* spp., *Gelidium* Lamouroux, *Ectocarpus* Lyngbye and *Halopteris filicina* (Grat.) Kütz. were found on the leaves only, whereas, *Plocamium cartilagineum*, *Punctaria* Greville, *Rhodophyllis divaricata* (Stackh.) Papenf., *Dictyota dichotoma* (Huds.) Lamour, and *Polysiphonia* Greville were found only on the dead leaf sheaths and/or rhizomes. *Cladophora*, *Enteromorpha* link in Nees, *Ulva lactuca* L., *Pilayella littoralis*, *Antithamnion spirographidis* Schiffner and *Ceramium rubrum* were found on leaves, dead leaf sheaths and rhizomes.

Epiphytes were detected in small quantities on leaf 4 but were rarely if ever present on leaf 5 or younger leaves. Results (Fig. 2) clearly indicate that the older the leaf the greater was the percentage of leaves with epiphytes. The mean

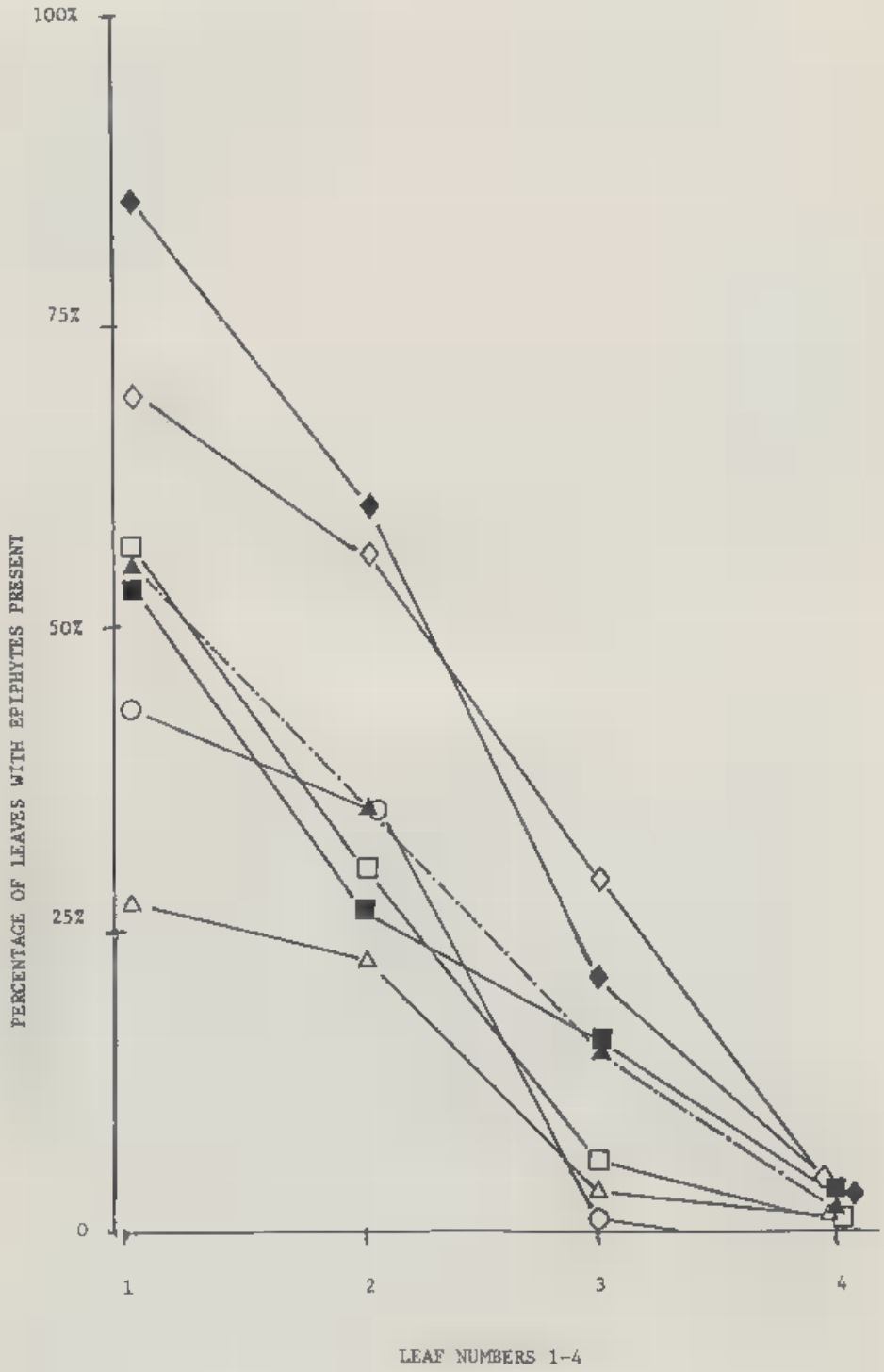

Fig. 2. — Shows the percentage of leaves that had epiphytes for leaves 1, 2, 3 and 4 for the six sample sites along with the mean value (—.—.—) for all sites. Currabinny ◆, Spike Island ○, White Bay □, Money Point ◇, Charles Fort ■, and Ventry △.

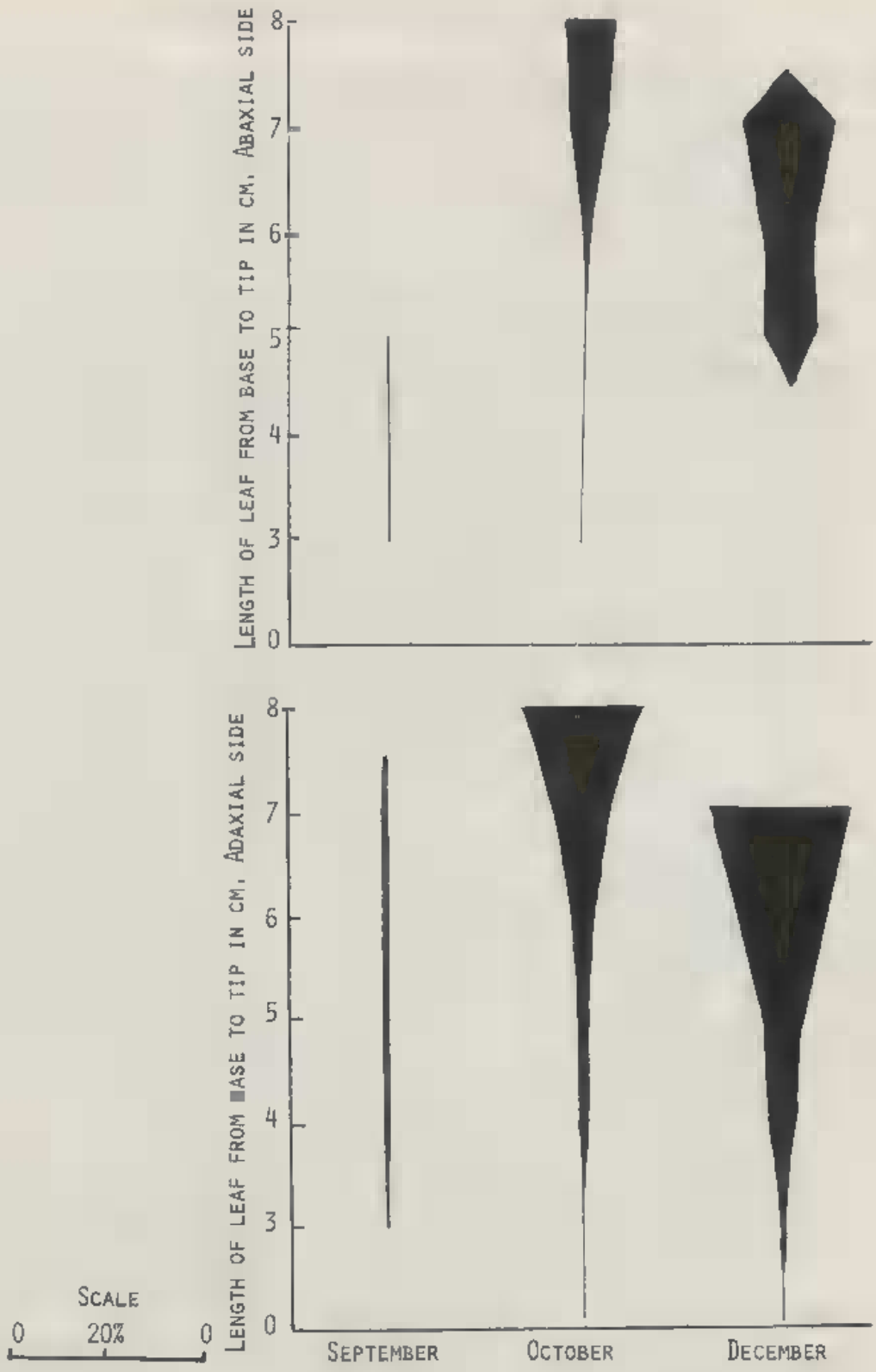

Fig. 3. — Shows the comparison of the percentage cover of *Fosliella* spp. on both the adaxial and abaxial sides of *Zostera* leaves in September, October and December.

values for all sites showed that this relationship was expressed by ■ straight line and was most evident at Currabinny and least evident at Ventry. JACOBS et al. (loc. cit.) found a similar distribution of the epiphytes on the four outermost leaves of intertidal *Zostera*. Although the diversity of epiphytes was greatest at Ventry, the percentage of leaves with epiphytes was very small and, in fact, was almost the same for leaf 1 and 2.

The crustose red alga, *Fosliella* was first noticed on the leaves in Ventry in September and was present only up to December, at which time it was no longer found at the tips of the leaves and by February it was absent from all leaves (Fig. 3). It occurred in abundance on dead leaf sheaths throughout the summer months. From September to December there was a greater percentage cover of *Fosliella* on the adaxial side of the leaf (Fig. 3). *Fosliella* was most abundant near the leaf tip (the first and longest living part available for colonization) and was only found near the base of the leaf on the adaxial side in October and December.

The outermost (oldest) leaf on each plant from Ventry was graded according to length, size, class and the mean percentage cover of *Fosliella* was determined for both the adaxial and abaxial sides for each size class. Results (Fig. 4) show that there is an almost linear relationship for both sides indicating that the longer the leaf the greater the percentage cover of *Fosliella*. In the younger stages, the adaxial face tends to be colonized more than the abaxial face but ■ the leaves lengthen this difference tends to be minimised.

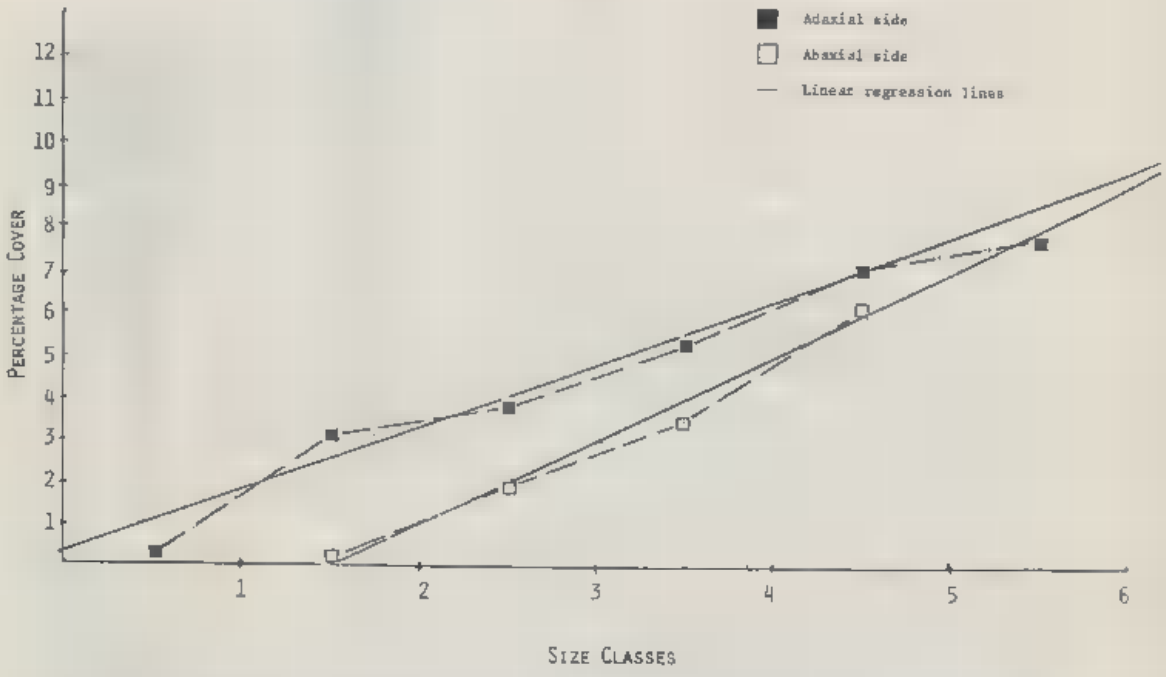

Fig. 4. – Shows the percentage cover for both the adaxial ■ and abaxial □ sides of the leaves in six different classes of leaf lengths (class 1 to 6 were 0-30, 30-40, 40-50, 50-60, 60-70, and 70-80 cm respectively).

Both *Cladophora* and *Plocamium* grew entangled in the rhizomes and/or dead leaf sheaths and although not organically connected to the host plant, the frequency with which they were found in this manner was too great to be ignored. Almost all of the *Plocamium* specimens consisted either entirely or in part of reflexed branches, i. e. *P. coccineum* var. *uncinatum* (C. Ag.) J. Ag. «not common in the British Isles but occurs more frequently in the Mediterranean» (DIXON & IRVINE, 1977). The reflexed condition would appear to be a response to this environment. The association of *Plocamium* with *Zostera* does not appear to have been previously reported. *In situ* observations in Ventry at depths down to 10 m below C.D. showed that *Cladophora* can become detached and form loose masses in between the *Zostera* or drift onto the shore and, by the churning effect of the waves on the strand, form rope-like or even spherical masses. Thus on Ventry beach on at least two recent occasions masses of *Cladophora* balls (aegagropilae) up to 3 cm in diameter have been found. WHITTAKER & FARNHAM (1983) noted that *Cladophora* spp. (called locally «flannel weed») grew entangled around the base of *Zostera* as did *Enteromorpha flexuosa*. DEN HARTOG (1982) has referred to loose lying algae as an important component in *Zostera marina* community but did not refer to *Cladophora*.

DISCUSSION

Only the following isolated records of *Zostera* algal epiphytes are to be found for Ireland, some of which were found in drift and some of the species are no longer recognised.

Cladophora corynartha (FOSLIE, 1899); *Rhodophysema georgii* (WEISS, 1900); *Cladophora rudolphiana, Cladophora cornea* var. *verticillata, Cladophora corynartha* var. *spinescens, Leptonema fasciculatum* var. *subcylindrica* and *Giraudia sphacelaroides* (NEWTON, 1931); *Melobesia farinosa* (SCANNELL, 1969); *Cladosiphon zosterae* (NORTON, 1970); *Fosliella lejolisii, Cladosiphon zosterae*, and *Mesogloia* sp., (HISCOCK & HISCOCK, 1980). COTTON (1912) in a survey of the Clare Island district has the following to say apparently (but with some ambiguity) with reference to *Zostera* epiphytes; «of the larger epiphytes the following are usually frequent in their respective seasons» and COTTON then listed some 16 macrospecies and 19 microspecies. REES (1931) did list eight species as occurring on *Zostera* in and around Lough Ine.

It is not absolutely clear whether or not COTTON's list refers to *Zostera* epiphytes and apart from his brief reference to «their respective seasons» neither he or REES gave any data on the depths of the *Zostera* or the distribution of the epiphytes on the host. JACOBS et al. (loc. cit.) worked in the intertidal and VAN DEN ENDE & HAAGE (loc. cit.) do not appear to give any details of depths, (but it seems likely that they worked in the intertidal) and collected only in March and April. Recording of depths is important in view of the fact that JACOBS et al. (loc. cit.) found that even in the intertidal the frequency of occurrence of Rhodophyceae increased with depth.

The almost complete lack of data of subtidal *Zostera* epiphytes limits comparisons with other surveys since the latter appear to have all been carried out in the intertidal.

Neither *Plocamium* nor *Cladophora* were recorded during either of the Roscoff studies although both were of frequent occurrence in the current study and *Cladophora* has also previously been listed by other Irish workers as a *Zostera* epiphyte. *Cladosiphon zosterae* (J. Ag.) Kylin and *Rhodophysema georgii* Batt. were not found during the present study but were both noted by the authors on *Zostera* in Ventry, in June 1982 and in September 1982, respectively and were both listed by COTTON but not by REES. Similarly JACOBS et al. did not record the host specific *Rhodophysema georgii* during their investigation although it was found at Roscoff on several other occasions by them, by DANGEARD (1934), J. FELDMANN (1954) and by VAN DEN ENDE & HAAGE, and DEN HARTOG (1976). Likewise *Audouinella (Acrochaetium)* was not recorded at the time of this study although it was observed on other occasions by the authors. *Erythrotrichia* recorded by COTTON was not found.

HARLIN stated that an epiphyte in «the general sense is any organism that lives upon a plant». However, in the current survey some species were found loosely interwoven with the rhizomes and/or dead leaf sheaths but were not included in the results as it was thought that their occurrence there was accidental. These included, *Ptilota plumosa* (Huds.) C. Ag., *Phycodrys rubens* (L.) Batt. and *Callophyllis laciniata* (Huds.) Kütz. JACOBS et al. (loc. cit.) included *Asparagopsis armata* Harv. among their list of epiphytes but do not appear to have described either the stage (gametophyte or sporophyte) or relationship that this species had with the host plant. HISCOCK & HISCOCK (loc. cit.) also noted *Falkenbergia* phase of *Asparagopsis armata* attached to *Zostera* bases.

According to JACOBS (1982) a seagrass ecosystem has to be regarded as a functional and structural unit and «the structural elements include (1) leaf-epiphytes (2) rhizome-epiphytes on the seagrass plants and (3) a mat of more or less loose-lying algae between the shoots» but he added that «in *Zostera* beds no algae are found on the rhizomes». Likewise VAN DEN ENDE & HAAGE did not find any epiphytes on the rhizomes and DEN HARTOG (1982) excluded «rhizomatic parts» of *Zostera marina* as a site for algal epiphytes while JACOBS et al. found no algae on the leaf sheaths. In contrast, the results of the present survey showed that the area of the rhizomes, roots and associated dead leaf sheaths, can be an important algal site, especially for diatoms. *Enteromorpha* was among the algae that was often found loosely associated with the rhizomatic parts but a careful examination of some material collected from Spike Island site showed that it was growing firmly attached beneath the surface of old dead parts of attached rhizomes as were some 2.5 m long *Chorda filum* (L.) Stackh. plants.

Results of the present survey showed a variation in the epiphytic flora between stations but this is not surprising in view of the large number of abiotic factors that control the epiphytic components e. g. sediment scouring, water

movements, currents, light, nutrients, and temperatures. The effect of the *Zostera* leaves rubbing off each other and the ephemeral nature of *Zostera* i. e. the fact that the leaves rarely survive more than about eighty days probably also control the epiphytic components.

The only species of *Fosliella* recorded by JACOBS et al. was *F. lejolisii* but, as they pointed out, since the crusts of this genus are difficult to distinguish it is not improbable that other species are present at Roscoff. In the current study due to the assistance given by CHAMBERLAIN some four species of the genus were recorded. These included *Fosliella limitata* (Foslie) Ganesan ■ species of rare occurrence reported by CHAMBERLAIN (1977) on *Zostera marina* near the Isle of Wight and apparently not previously recorded from Ireland. CHAMBERLAIN (pers. comm.) encountered ■ ■■■ species of *Fosliella* on *Zostera marina* in 1981 and some of the Ventry material found during the present study is said, by CHAMBERLAIN, to also belong to this new species. The genus *Fosliella* showed a preference for the adaxial face although VAN DEN ENDE & HAAGE found no difference in the epiphytes on the two faces and JACOBS et al. found negligible differences in species richness and abundance between the leaf sides. JACOBS et al. and VAN DEN ENDE & HAAGE stated that since the leaves are upright they would not expect ■ difference. They are however, not correct in assuming equal orientation of both leaf faces. *In situ* observations show that in almost all mature leaves there is a distinction between leaf faces due to pronounced leaf curvature. Studies on the distribution of *Fosliella* and observations of other species support the findings of JACOBS et al. in that colonization of the *Zostera* leaves occurred nearer the tips and not near the bases as described by VAN DEN ENDE & HAAGE.

There would appear to be an almost complete lack of knowledge of the epiphytes of subtidal *Zostera* and more detailed work on the seasonality and distribution of the epiphytes on the different parts of the *Zostera* is desirable from a number of subtidal *Zostera* beds not just in Ireland but elsewhere in western Europe to allow for comparison.

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